Fiscal Year:	FY 2012	**Task Last Updated:**	FY 01/08/2013
PI Name:	Dinges, David F. Ph.D.		
Project Title:	Optical Computer Recognition of Stress, Affect and Fatigue during Performance in Spaceflight		
Division Name:	Human Research		
Program/Discipline:	NSBRI		
Program/Discipline--Element/Subdiscipline:	NSBRI--Neurobehavioral and Psychosocial Factors Team		
Joint Agency Name:		**TechPort:**	Yes
Human Research Program Elements:	(1) **BHP**:Behavioral Health & Performance (archival in 2017)		
Human Research Program Risks:	(1) **BMed**:Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders		
Space Biology Element:	None		
Space Biology Cross-Element Discipline:	None		
Space Biology Special Category:	None		
PI Email:	dinges@pennmedicine.upenn.edu	**Fax:**	FY
PI Organization Type:	UNIVERSITY	**Phone:**	215-898-9949
Organization Name:	University of Pennsylvania		
PI Address 1:	Department of Psychiatry		
PI Address 2:	423 Service Dr., 1013 Blockley Hall		
PI Web Page:			
City:	Philadelphia	**State:**	PA
Zip Code:	19104-4209	**Congressional District:**	2
Comments:			
Project Type:	Ground	**Solicitation / Funding Source:**	2007 Crew Health NNJ07ZSA002N
Start Date:	05/01/2008	**End Date:**	09/30/2012
No. of Post Docs:	1	**No. of PhD Degrees:**	0
No. of PhD Candidates:	0	**No. of Master' Degrees:**	0
No. of Master's Candidates:	0	**No. of Bachelor's Degrees:**	0
No. of Bachelor's Candidates:	3	**Monitoring Center:**	NSBRI
Contact Monitor:		**Contact Phone:**	
Contact Email:			
Flight Program:			
Flight Assignment:			
Key Personnel Changes/Previous PI:			
COI Name (Institution):	Metaxas, Dimitris (Rutgers University) Goel, Namni (University of Pennsylvania) Basner, Mathias (University of Pennsylvania)		
Grant/Contract No.:	NCC 9-58-NBPF01601		
Performance Goal No.:			
Performance Goal Text:			

Task Description:	Astronauts must maintain high-level performance while experiencing demanding workload and work schedules, extreme environmental risks, and psychosocial stressors in space (e.g., isolation, confinement). Stress, negative emotions, and fatigue can jeopardize their cognitive performance and neurobehavioral status. The proposed research is developing and validating an objective, unobtrusive, computational model-based tracker of the human face that reliably identifies when astronauts are experiencing stress, emotion, and fatigue at levels that compromise performance in space. This optical computer recognition (OCR) system will provide feedback to them for autonomous selection of countermeasures for stress, depression, and fatigue. The project is being accomplished through collaborative efforts of Dr. David Dinges (Unit for Experimental Psychiatry) at the Perelman School of Medicine at the University of Pennsylvania, and Dr. Dimitris Metaxas (Computational Biomedicine Imaging and Modeling Center) at Rutgers University. The project has four specific aims: (1) Create an OCR system capable of monitoring facial displays of specific emotions (i.e., angry, happy, and sad). (2) Improve our current OCR system's ability to detect facial expressions of high versus low performance-induced stress. (3) Develop OCR algorithms to identify fatigue due to sleep loss based on slow eyelid closures (PERCLOS). (4) Test the technical feasibility of data acquisition and reliability of the advanced OCR system in spaceflight analogs that contain neurobehavioral stressors relevant to spaceflight. The project has primary relevance to strategic goals of the National Space Biomedical Research Institute (NSBRI) Neurobehavioral and Psychosocial Factors (NBPF) Team. The two major laboratory experiments on the accuracy of OCR using a single camera were completed in the final funding period. One study involved measuring how well the single-camera OCR algorithm accurately tracked emotional expressions in N= 31 healthy subjects who underwent emotional induction techniques. Preliminary analyses of the overall extent to which the initial 1-camera OCR algorithm could identify specific emotional expressions in many individuals with limited training revealed that the algorithm often failed to discriminate among emotions. That is, the algorithm had modest sensitivity and low specificity (i.e., it selected negative emotions too often and failed to discriminate among them). Although the facial expression models being used by the tracker were appropriate, it became apparent that a great deal of OCR inaccuracy was due to problems in identifying facial expressions when the face was partially out of view, which occurs frequently as people move their heads in all dimensional planes as they move about, work, etc. Thus, although we trained the OCR facial expression models with frontal images of facial expressions of emotion, the videos of subjects experiencing emotions would many times show subjects in non-frontal poses. The OCR algorithm model would then fail to correctly recognize the facial expression. To correct for this problem, the Metaxas Lab developed a sufficiently approximate warping transformation to warp the tracked face to a frontal pose (which is what the OCR algorithm expects to evaluate), as well as enhancing the algorithm with other analytic techniques that improve single-camera face tracking and extrapolation of facial expressions when the face is moving and/or partially out of view. The second validation experiment was conducted on a separate group of N=33 healthy adults randomized to either sleep deprivation (N=18) or no sleep deprivation (N=15). The total number of subjects to be studied was decreased in order to focus on improved computational detection of emotion and fatigue. The goal of this experiment was to determine the extent to which the model-based OCR algorithm validly detected and tracked ocular changes in slow eyelid closures (PERCLOS) when sleep deprived and when not sleep deprived, and the extent to which the PERCLOS measure reliably tracked lapses of attention during psychomotor vigilance test (PVT) performance. Experiment 2 was our first attempt to track PERCLOS with a novel 1-camera OCR algorithm. The results were very promising. Subjects completed a 20-min PVT every 2 h while awake. Images of the face were recorded during each performance test. PERCLOS was manually scored frame-by-frame by 4 human scorers blinded to sleep condition and time of testing, and it was scored by the OCR algorithm (programmers blind to these factors). Coherence was calculated as the extent to which PVT lapses of performance were tracked by OCR-scored PERCLOS while subjects were and were not sleep deprived. Although OCR PERCLOS did not predict the occurrence of every PVT performance lapse, it was remarkably accurate for the vast majority of them, showing excellent coherence across a 36-h period of sleep deprivation, and a marked increase after sleep deprivation relative to before it, but no change in subjects who were resistant to the effects of sleep deprivation on PVT performance, or subjects who were not sleep deprived. Thus, the sensitivity of the current 1-camera OCR algorithm for detecting PERCLOS as an index of fatigue-related performance failures was 73.3% and the specificity was 89.1%. This is excellent sensitivity-specificity. These data confirm that the OCR PERCLOS detector rarely yielded false positives, and that it was acceptably high in sensitivity to predicting performance lapses. OCR PERCLOS will never reach 100% sensitivity when validated against PVT lapses because some performance lapses can occur when the eyelids are open. The findings suggest a single-camera OCR algorithm could detect the presence of performance-impairing fatigue from sleep loss in spaceflight.
Rationale for HRP Directed Research:	
Research Impact/Earth Benefits:	The study focuses on the ability of an unobtrusive, automated optical computer recognition (OCR) technology to detect psychological stress, emotion, and fatigue during operational performance. The knowledge gained has the potential to identify an objective, unobtrusive, automated method for the recognition, monitoring, and management of the risks of neurobehavioral dysfunction in affect and alertness in spaceflight and in many Earth-based safety-sensitive occupations, such as NASA mission controllers, first responders, transportation workers (e.g., truck drivers, train conductors, airline pilots); operators in safety-sensitive industries (e.g., power plant control rooms); and military personnel.
Task Progress:	The two major laboratory experiments on the accuracy of OCR using a single camera were completed in the final funding period. One study involved measuring how well the single-camera OCR algorithm accurately tracked emotional expressions in healthy subjects who underwent emotional induction techniques. Preliminary analyses of the overall extent to which the initial 1-camera OCR algorithm could identify specific emotional expressions in many individuals with limited training revealed that the algorithm often failed to discriminate among emotions. That is, the algorithm had modest sensitivity and low specificity (i.e., it selected negative emotions too often and failed to discriminate among them). Although the facial expression models being used by the tracker were appropriate, it became apparent that a great deal of OCR inaccuracy was due to problems in identifying facial expressions when the face was partially out of view, which occurs frequently as people move their heads in all dimensional planes as they move about, work, etc. Thus, although we trained the OCR facial expression models with frontal images of facial expressions of emotion, the videos of subjects experiencing emotions would many times show subjects in non-frontal poses. The OCR algorithm model would then fail to correctly recognize the facial expression. To correct for this problem, the Metaxas Lab developed a sufficiently approximate warping transformation to warp the tracked face to a frontal pose (which is what the OCR algorithm expects to evaluate), as well as enhancing the algorithm with other analytic techniques that improve single-camera face tracking and extrapolation of facial expressions when the face is moving and/or partially out of view.

	The second validation experiment was conducted on a separate group of healthy adults randomized to either sleep deprivation or no sleep deprivation. The experiment sought to determine the extent to which the OCR algorithm detected ocular changes in slow eyelid closures (PERCLOS), and the extent to which the OCR PERCLOS measure reliably tracked lapses of attention during PVT performance. This was our first attempt to track PERCLOS with a 1-camera OCR algorithm. Subjects completed a 20-min PVT every 2 h while awake. Images of the face were recorded during each performance test. Coherence was calculated as the extent to which PVT lapses of performance were tracked by OCR-scored PERCLOS while subjects were and were not sleep deprived. The study revealed that the 1-camera OCR algorithm for PERCLOS had 73% sensitivity and 89% specificity for PVT performance lapses, thus confirming that the OCR PERCLOS detector rarely yielded false positives, and that it was acceptably high in sensitivity to fatigue-related performance risks in spaceflight.
Bibliography Type:	Description: (Last Updated: 05/08/2025)
Abstracts for Journals and Proceedings	Di Antonio A, Moreta M, Michael N, Muto J, Minkel JD, Yang F, Htaik O, Metaxas DN, Dinges DF. "An Objective Unobtrusive Model-Based Tracker of Facial Expressions of Negative and Positive Emotions in Space Flight." 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. , Feb-2012
Abstracts for Journals and Proceedings	Jones CW, Basner M, Goel N, Metaxas D, Dinges DF. "Unobtrusive Tracking of Slow Eyelid Closures as a Measure of Fatigue From Sleep Loss." 25th Annual Meeting of the Associated Professional Sleep Societies, LLC 2011, Minneapolis, MN, June 11-15, 2011. Sleep 2011;34 Suppl:A114. , Jun-2011
Abstracts for Journals and Proceedings	Jones CW, Basner M, Yu X, Yang F, Goel N, Metaxas D, Dinges DF. "Unobtrusive Tracking of Slow Eyelid Closures as a Measure of Fatigue from Sleep Loss." 26th Annual Meeting of the Associated Professional Sleep Societies, Boston, MA, June 9-13, 2012. Sleep. 2012;35 Suppl:A110. , Jun-2012
Abstracts for Journals and Proceedings	Jones CW, Yang F, Basner M, Goel N, Abe T, Metaxas D, Dinges DF. "Unobtrusive Tracking of PERCLOS as a Measure of Sleepiness-Related Fatigue in Space Flight." 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. 2012 NASA Human Research Program Investigators' Workshop, Houston, TX, February 14-16, 2012. , Feb-2012
Articles in Peer-reviewed Journals	Balkin TJ, Horrey WJ, Graeber RC, Czeisler CA, Dinges DF. "The challenges and opportunities of technological approaches to fatigue management." Accident Analysis and Prevention. 2011 Mar;43(2):565-72. Review. http://dx.doi.org/10.1016/j.aap.2009.12.006 ; PubMed PMID: 21130217 , Mar-2011
Articles in Peer-reviewed Journals	Minkel JD, Banks S, Htaik O, Moreta MC, Jones CW, McGlinchey EL, Simpson NS, Dinges DF. "Sleep deprivation and stressors: Evidence for elevated negative affect in response to mild stressors when sleep deprived." Emotion. 2012 Oct;12(5):1015-20. Epub 2012 Feb 6. http://dx.doi.org/10.1037/a0026871 ; PubMed PMID: 22309720 , Oct-2012
Papers from Meeting Proceedings	Hu Q, Yang F, Yang P, Peng X, Zhong L, Zhang S, Metaxas DN. "Facial Expression Recognition under Large Pose Variation." 10th IEEE International Conference on Automatic Face and Gesture Recognition 2013, Shanghai, China, April 22-26, 2013. 10th IEEE International Conference on Automatic Face and Gesture Recognition 2013, Shanghai, China, April 22-26, 2013. , Apr-2013
Papers from Meeting Proceedings	Yang F, Huang J, Metaxas DM. "Sparse Shape Registration for Occluded Facial Feature Localization." 2011 IEEE International Conference on Automatic Face and Gesture Recognition, Santa Barbara, California, March 21-25, 2011. 2011 IEEE International Conference on Automatic Face and Gesture Recognition, Santa Barbara, California, March 21-25, 2011. p. 272-277. http://dx.doi.org/10.1109/FG.2011.5771410 , Mar-2011
Papers from Meeting Proceedings	Yang F, Huang J, Yang P, Metaxas DM. "Eye Localization through Multiscale Sparse Dictionaries." 2011 IEEE International Conference on Automatic Face and Gesture Recognition, Santa Barbara, California, March 21-25, 2011. 2011 IEEE International Conference on Automatic Face and Gesture Recognition, Santa Barbara, California, March 21-25, 2011. p. 514-518. http://dx.doi.org/10.1109/FG.2011.5771450 , Mar-2011